

Heat Rate Enhancement of IGCC Power Plant Coupled with Solar Thermal Power Plant

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Abstract- Integrated gasification combined cycle power plant (IGCC) has shown the potential of having higher operating thermal efficiency, than supercritical thermal power plants as it combines the advantages of coal gasification and combined cycle power plant. Solar thermal plant has shown great promise to augment the thermal efficiency of the fossil based power plants and reducing CO₂ emissions. In this research paper, impact of integrating solar thermal power plant utilizing linear Fresnel collectors (LFC) with IGCC plant on plant heat rate has been simulated. The feed water from condenser is connected to series of LFC modules and preheated before admitting into de-aerator instead of feed water being pre-heated in feed water heater using steam from turbine extractions. The impact of solar feed water heating on plant heat rate and plant thermal efficiency has been evaluated over entire day.

Keywords—Concentrated solar technology, Linear Fresnel collectors, IGCC, combined cycle, gas turbine, gasification

1. Introduction

Concentrated solar thermal technology (CST) has shown great potential to produce steam for power generation since beginning of eighties. It uses reflecting surfaces to focus solar energy onto collectors, generating steam for industrial as well as power generation purposes. For power generation, one of the short coming of CST technology is sunlight availability during night and cloudy seasons, which requires energy storage. On the other side, fossil based power plants have high availability and reliability but generate significant amount of CO₂ emissions. A novel approach is to combine the advantage of CST and conventional power plant.[1-6]. Bakos et al [4] has evaluated the integration of parabolic trough modules with 300 MW lignite fired power plant using dynamic simulations and showed that power output of the plant can be raised up to 27 MW using the integrated approach and annual reduction of CO₂ can be achieved up to 45000 tons. Suresh et al.[6], has studied the solar aided feed water heating in 500 MW subcritical and 660 MW super critical thermal power plant and suggested that 5- 6 % reduction in coal consumption under fuel saving mode and up to

6200 tonnes per annum CO₂ reduction can be achieved by substituting steam extractions in HP and LP feed water heater with solar heat. Zhai et al. [7] studied the feed water heating with solar heat via heating feed water with heated oil through solar, eliminating HP heater and associated steam extraction for 600 MW power plant. It has suggested that net power output can be enhanced up to 30 MW. Hue et al. [8] has simulated the feed water heating using solar concentrators for 100 % replacement of all five (HP, IP and LP) feed water heaters, 10 % replacement of all five feed water heater and 100 % replacement of IP(intermediate pressure) feed water heaters. Integrated gasification and combined cycle(IGCC) power plant uses coal as a fuel and generates syngas through gasification process and utilizes syngas in Gas turbine to generate power. The excess heat in the GT exhaust gas is being utilized to generate steam which can be used in Rankine cycle to generate power. IGCC power plant efficiency can be further augmented by integrating solar thermal power with the plant. In this paper, the concept of feed water heating in HP or LP heaters via solar thermal plant is extended to IGCC based power plant and study is carried to find potential in improving overall plant efficiency.

2. Model Development

The IGCC power plant flow sheet for the base load equivalent to 200 MW was simulated as shown in Fig.1 in the commercial software [9]. The software can be used to carry out over all heat and material balance for the IGCC power plant. The entire flow sheet for the IGCC power plant shown in Fig.1 was built in the software environment and heat and material balance calculations were performed. The net heat rate, net plant efficiency and power output was calculated for the base case. In the base case, feed water from Ash cooler was heated through steam extraction in LP heater from 113 to 128 °C as shown in Fig.1. In the new approach, the solar thermal collectors were used to preheat the feed water heater from 113 °C to 128 °C instead of LP heater as shown in Fig.2. The Line focusing collector was used to model Linear Fresnel reflector (LFC) in the tool.

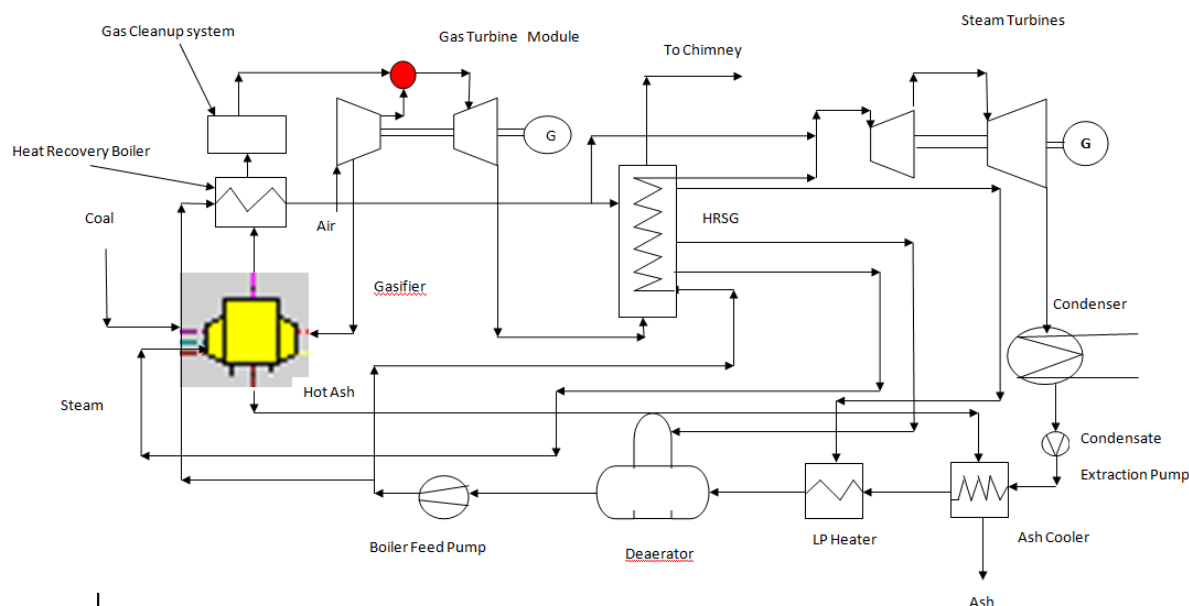


Fig. 1. Schematic of the IGCC power plant

3. Simulation Results and Discussions

3.1. Impact of DNI on Feed Water Heating

In order to understand the impact of heating feed water through LFCs, the feed water flow was split in five streams and each steam has nine LFC modules in series. Thus, entire LFC network had total 45 collectors. The feed water from condenser is pumped through LFC network as shown in Fig.2 and enters into LP Heater. The feed water was desired to heat from 113 °C to 128 °C before it enters into de aerator. The process is designed in such a way that during cloudy season and night times, the LFC network will be bypassed and feed water will be heated completely via LP heater, which utilises the steam extraction from turbine. During day

The multiple LFC modules were connected in series as shown in Fig.2. The inbuilt database for Mirrox LFC was used for the study. As shown in Fig.2, It was envisaged that during the day the feed water will be fed to LFCs and passes through LP heater thus eliminating/reducing steam extraction from turbine or HRSG system. During the day time, valve- V2- is closed and feed water is diverted to LFC modules and fed to LP heater, while the steam flow through valve V-1 is controlled to achieve 128 °C. During the night time and cloudy season the feed water will bypass solar collector system by closing V-3 valve and subsequently opening V-2 valve. It will be heated by steam from HRSG through LP heater. The sun module was configured to use “NREL” method to calculate sun positions and sun angles. The Hyderabad, India was chosen as location and average “DNI” data for last 10 year were taken for simulation [10].

time, the feed water will pass through LFC network, which will heat the feed water from 113 °C depending upon the DNI availability and rest will be heated in LP heater by extracting steam from turbine to 128 °C. A sensitivity analysis is done on DNI impact on Power plant output and heat rate. The DNI was varied from 0 to 700 W/m² and the impact on power plant output has been observed. Fig.3 suggests that as DNI increases, the power plant output increases by 1 MW and plant heat rate decreases by 11 Kcal/KWh. Also as DNI increases, the amount of steam extraction also reduces from 6 ton/hr to 0 ton/hr as shown in Fig.4. Fig. 4 suggests that at DNI of 500 W/m² and greater, there is no need to heat feed water through LP heater as LFC network is self-sufficient to boost feed water temperature from 113 °C to 128 °C.

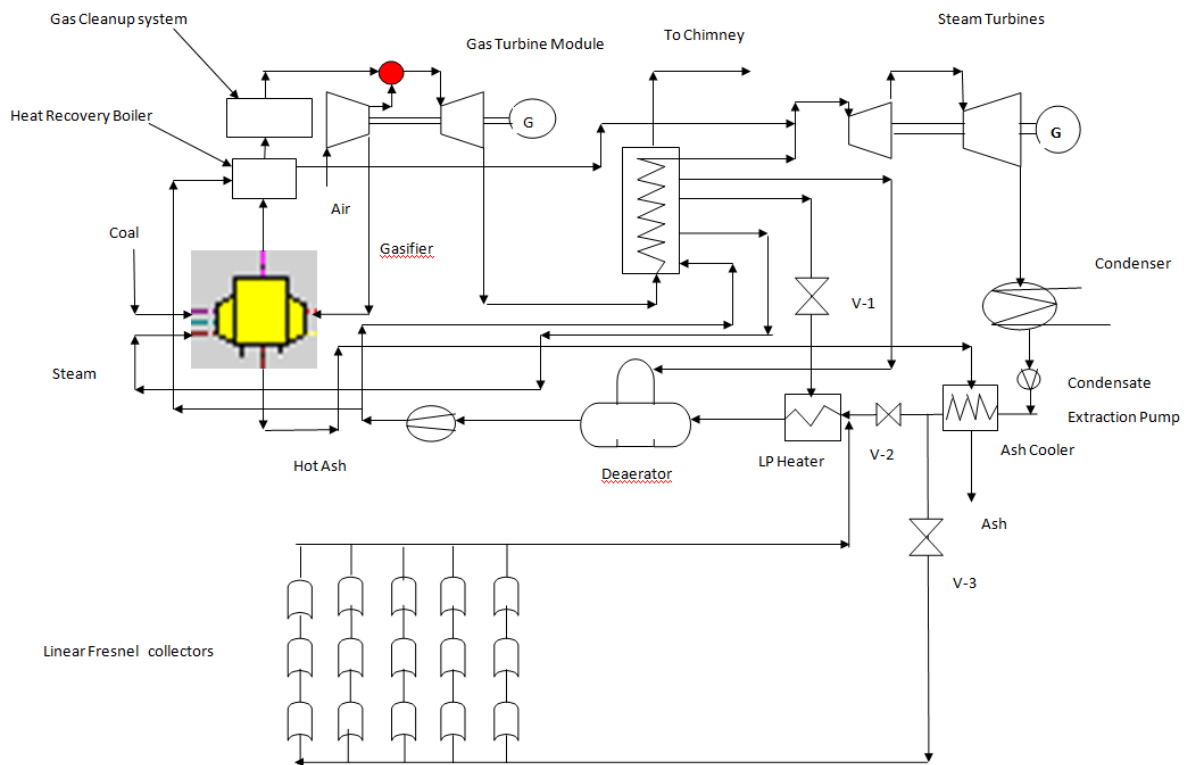


Fig. 2. Feed water heating in IGCC plant through Linear Fresnel collectors (LFC)

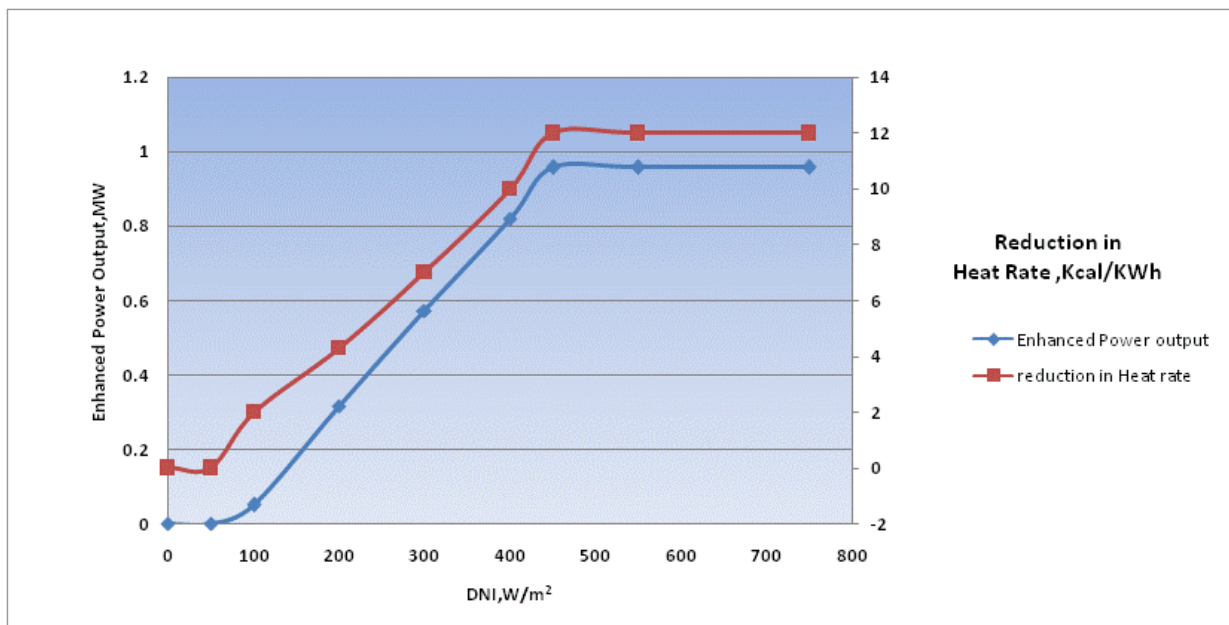


Fig. 3. Impact of DNI on Power output and plant heat rate

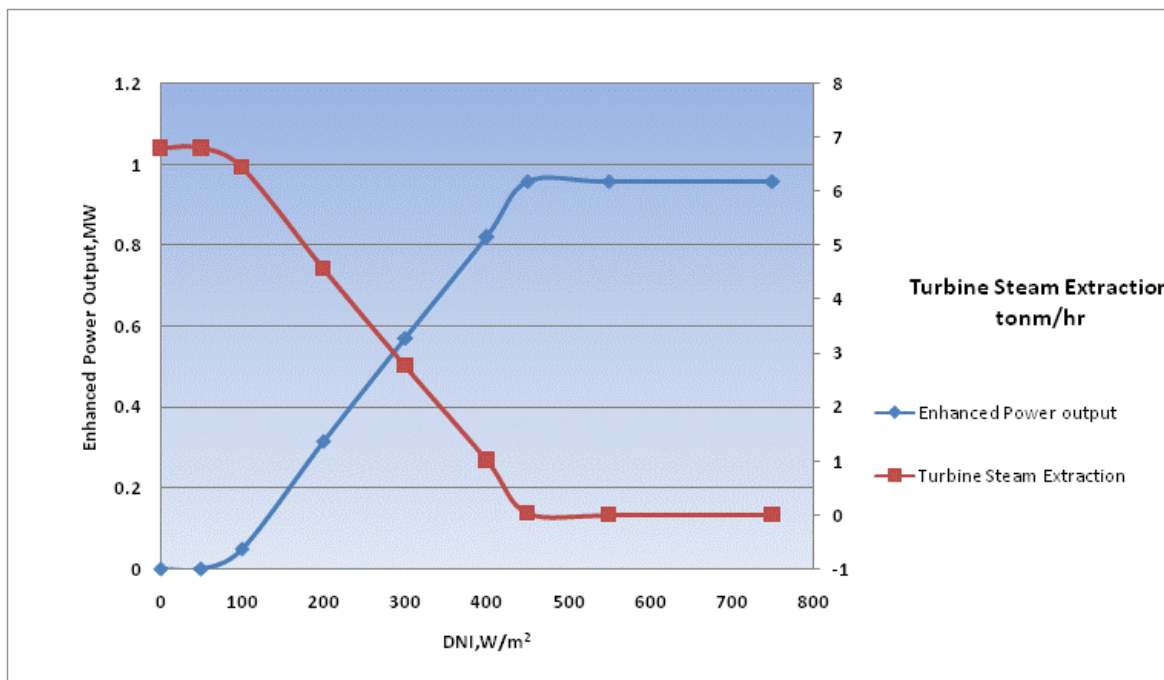


Fig. 4. Impact of DNI on Plant performance and turbine steam extraction

3.2. Analysis of Feed Water Heating for Entire Day

In order to analyse the performance of LFC network on plant output, the average DNI data for January month of last 10 years were chosen. The pseudo steady state simulation was carried out for every hour from morning 6 hrs to evening 18 hrs. It was also decided to observe the impact of number of LFC modules on plant performance. Three types of arrangement were considered for analysis.

1. 35 LFCs, (7 in series each row , total 5 rows)
2. 40 LFCs (8 in series each row, total 5 rows) and
3. 45 LFCs (9 in series each row , total 5 rows)

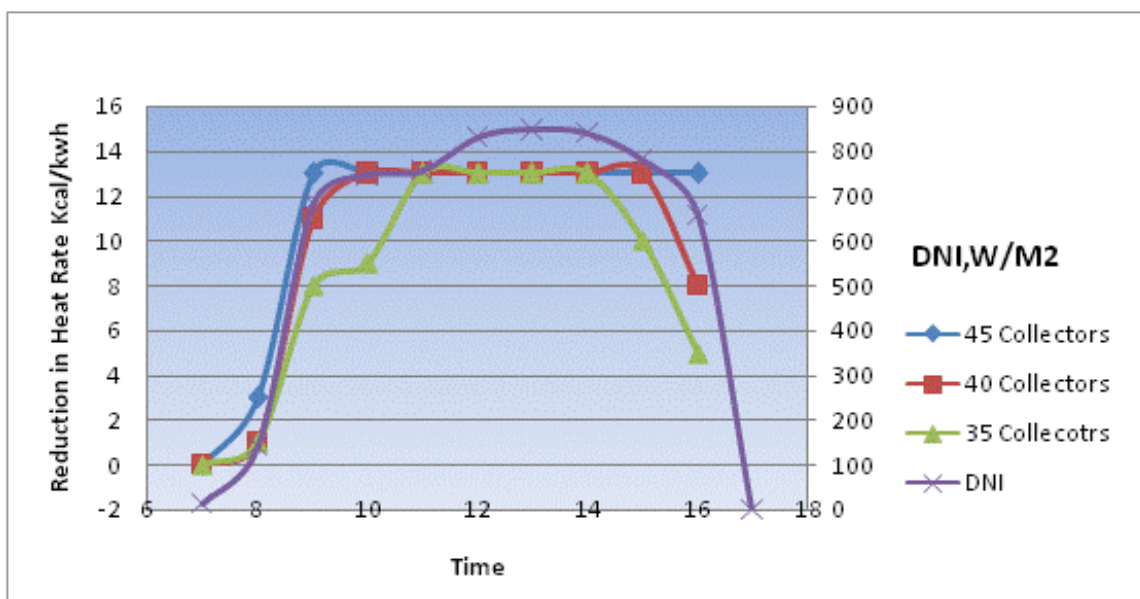


Fig.5. Heat rate variation of the plant throughput during the day

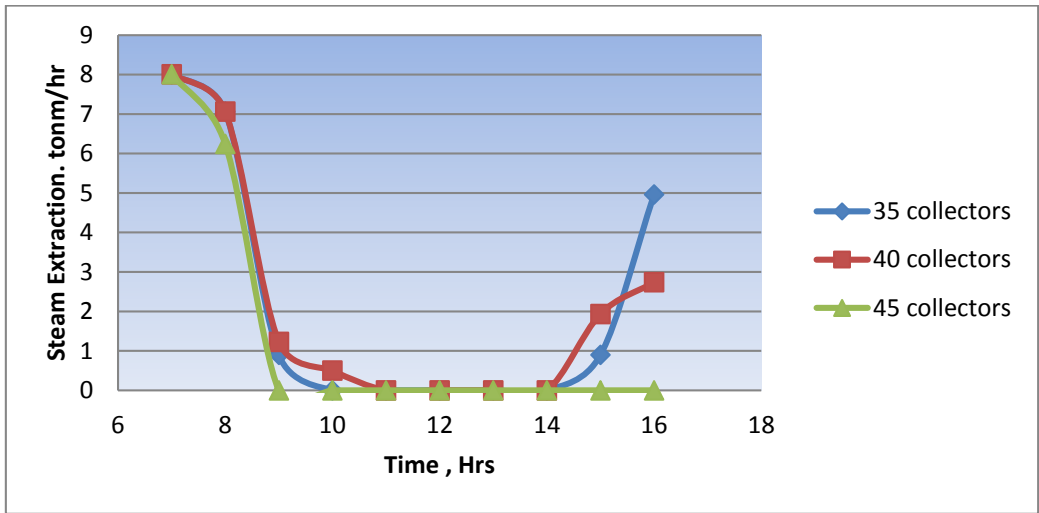


Fig. 6. Steam extraction from turbine during the day

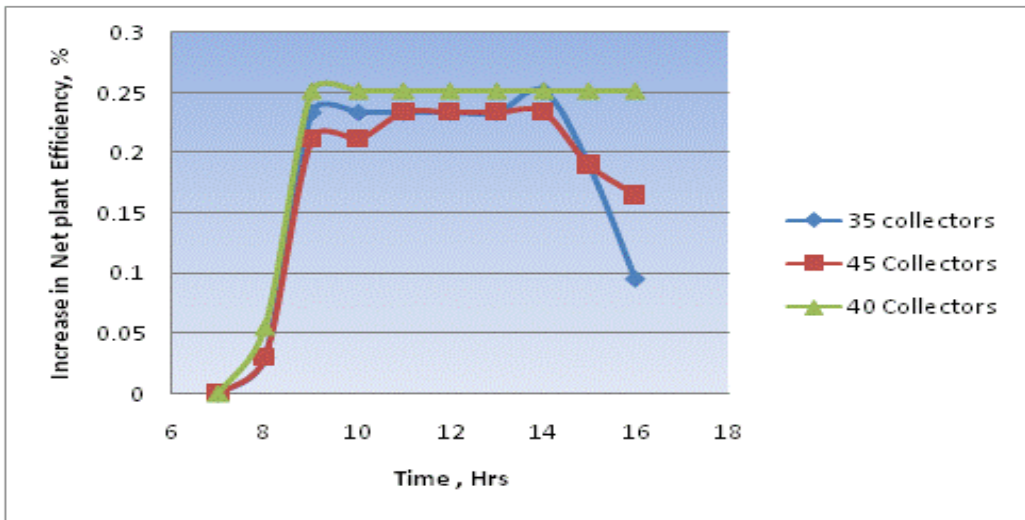


Fig. 7. Impact on gross plant efficiency during the day

Fig .5 compares the performance of the three arrangements of LFCs modules over entire day. The performance of the plant with 35, 40 and 45 collectors was simulated. In case of 35 collectors, plant heat rate reduces to 14 Kcal/KWh at 11 hrs in the morning from the prevailing heat rate at 6 hrs. It suggests that during 11 hrs to 14 hrs reduction of 14 Kcal/Kwh in plant heat rate can be achieved. In case of 40 collectors reduction of 14 Kcal/Kwh in heat rate was achieved at 10 hrs from the prevailing heat rate at 6 hrs. For 45 collectors, reduction of 14 Kcal/kwh in heat rate was achieved during 9 hrs to 16 hrs. Fig. 5 suggests that having collectors more than 45 will ensure higher availability of solar thermal energy which ensures minimum plant heat rate for longer hrs during the day. Fig. 6 shows the variations in steam extraction flow which is needed in LP heater, which follows the similar trend of heat rate. Fig .7 shows the extent of gross plant efficiency that can be enhanced through integrating LFC modules with IGCC

plant. The efficiency improvement up to 0.3 % can be achieved depending upon the number of collectors.

4. Conclusions

A simulation study was carried out for feed water heating in IGCC power plant by incorporating LFC modules. The following findings emerged.

1. The feed water heating via LFC module has a potential to increase power output by 1 MW for 200 MW equivalent IGCC power plants, which is equivalent to decrease in plant heat rate 14 Kcal/kWh.
2. During the day, the efficiency of entire plant integrated with LFC modules varies during day. The efficiency is highest during 10 hrs to 15 hrs.
3. Incorporating higher number of LFC modules will ensure higher plant efficiency or lower heat rate for long hrs during day. The techno economic analysis

is needed to come with optimal number of LFC modules.

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